Lesson 6

The Enigma of light

Time: 1 class period (if demo and second activity are conducted during the course of the first activity. Otherwise this will take 2 class periods)

HCPS III Benchmarks

SC.7.1.1 Design and safely conduct a scientific investigation to answer a question or test a hypothesis
SC.7.1.2 Explain the importance of replicable trials
SC.7.1.3 Explain the need to revise conclusions and explanations based on new scientific evidence
SC.8.1.1 Determine the link between evidence and the conclusion of an investigation
SC.8.2.2 Describe how scale and mathematical models can be used to support and explain scientific data

NSES

Abilities of technological design
Understandings about science and technology
Science and technology in society
Nature of science
Science as human endeavor

Learning objectives

1. Design and safely conduct an experiment to determine the amount of energy absorbed by water from sunlight

2. Construct a graph to observe the change in temperature over time

3. Observe that white light contains a spectrum of visible electromagnetic wavelengths that can be broken into components with a prism

4. Measure and record data from three different plants of the sugar concentration (Brix)

Background

What is light? Is it a particle? Is it a wavelength? Is it a string? Is it energy? Light is fundamental to life as we know it and yet it still eludes scientists today. Generally when we think of light we are referring to wavelengths in the visible spectrum that is the 400nm to 750nm wavelength, however the electromagnetic spectrum extends well beyond this narrow band in both directions. At night when stars twinkle, light can appear as a string because it is traveling so fast, 186,282 miles/sec to be more precise. In addition to being described as a wave, light can also be thought of as being a particle or a photon. Since energy is anything that can be converted into or measured as heat, light can also be said to have energy. It is this energy that plants are able to utilize in photosynthesis.

Activity - Measure the amount of energy in sunlight

Materials

Round bottomed flask
Rubber stopper
Thermometer
Water
Measuring beaker

This is a good activity to do with a partner to help with keeping track of time, observation, and recording. Use a round bottomed flask and fill with a known amount of water, a rubber stopper with a hole for a thermometer, and a thermometer. You can substitute volume (ml) for mass (g) with water even though the formula below uses mass for units because the density of water is 1 g/ml. Take the initial temperature of the water and record in the observation log. Leave in a place in or near the garden in full sun for a class period and take the temperature. Take at least three additional measurements at known time intervals for your graph. Record your results. Note this works best on a sunny day. Graph the temperature change vs time. You can calculate the amount of energy absorbed by the water from the sun using the formula:

Energy(calories) = ΔT(C°) * Mass H_2O (g) * Specific Heat (1 calorie/ g C°)

Option: Raise the flask to focus the sunlight over a piece of sage or other fragrant leaf like Ti or false sandalwood for a few minutes or until the paper begins to char. Why do you think the leaf chars? Charred paper can be composted when you are done.

Option: Focus light with a magnifying glass (convex). A 3x to 10x magnification works best for this..

Warning: Do not stare at the focused sunlight for more than a few seconds and do not focus the light on clothing or skin.

White light as we experience it through our vision is actually composed of varying wavelengths, including those in the visual spectrum. It is the varying wavelengths that are responsible for the different colors that we perceive. However there are also wavelengths beyond the visual spectrum such as infrared and ultraviolet. Other animals such as insects can sense the infrared wavelengths and use them to navigate their environment. Can you guess which color of the visible spectrum is closest in wavelength to infrared? How about ultraviolet?

Demo

Quartz or glass prism
White paper

Use a quartz or glass prism to demonstrate that white light is actually composed of all of the colors of a rainbow.

As you can see from the making fire from water construction there is quite a bit of energy in light. This energy in light, specifically in the ultraviolet spectrum, can damage your DNA in skin cells and cause the symptoms of sunburn. Likewise staring at the sun too long can make you go blind. Yet without exposure to light we would also go blind. We also might become vitamin D deficient as humans synthesize this essential nutrient from sunlight exposure. Fortunately, our body is able to repair DNA after exposure to ultraviolet light, although there is a limit to our ability to do this. As in many things in life, it is in balance where we find what is best for us.

The properties of light have been used to construct various instruments. For example, as light passes through a different substance, (from air), the light bends or refracts. Ernst Karl Abbe developed the first refractometer in 1874 after observing the refraction of light through different substances. Today this instrument is used by agriculturists and food scientists to measure the sugar content of fruits and vegetable.

Plants and algae are able to capture and utilize sunlight energy in a process known as **photosynthesis**. During photosynthesis plants convert CO_2 into organic compounds such as sugars (carbohydrates) see below.

$6CO_2 \quad + \; 6\,H_2O \quad \longrightarrow$
$C_6H_{12}0_6 \quad + \quad 6O_2$
carbon water chlorophyll
glucose oxygen
dioxide & sunlight
(sugar)

Respiration is the inverse reaction and complimentary to photosynthesis. In respiration the sugars produced by photosynthesis can also be consumed as energy.

$C_6H_{12}0_6 \quad + \quad 6O_2 \quad \longrightarrow$
$6CO_2 \quad + \; 6\,H_2O$
glucose oxygen
carbon water

dioxide

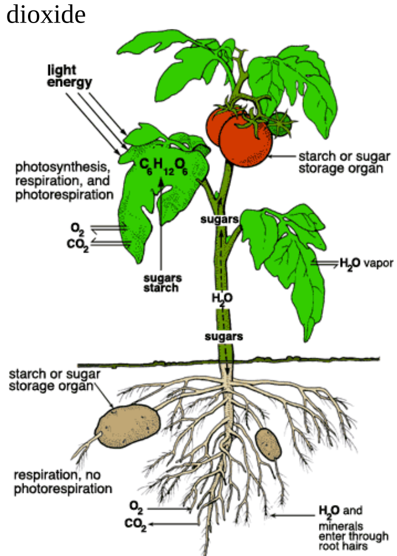


Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.

[Graphic from Oregon State Botany department's Botany Basics: Master Gardener Series Online Botany Module chapter on plant growth and development] retrieved 7/20/11 from http://extension.oregonstate.edu/mg/botany/growth.html)

Activity

Materials

Hand refractometer (aka salinometer) available at:
http://www.agriculturesolutions.com/Refractometers-/-Brix-Meters/View-all-products.html
www.amazon.com

Plants normally transport their sugars to growing fruits, storage organs, and other sinks throughout the plant. Sugars may also be converted into starch, another form of carbohydrate that is composed of several or more sugars bound together. Most plants do not store carbohydrates as sugars, however two well known plants that do may be in your garden. Can you guess what they are? They are sugar cane (Ko) and sugar beets, a special variety of the common beet. It was Columbus that introduced sugar cane to the Caribbean Islands. Subsequently slavery was established in order to meet the European demand for sweeteners, which previously was met with honey. Now that you have learned about the energy content of light and that plants are able to use this energy to store as sugars or carbohydrates, let's head out to the garden to test this theory out.

Your hand held refractometer is designed to measure sucrose or common table sugar. **Sucrose** is the common sugar stored in plants as well and is a disaccharide, composed of a glucose and fructose molecules. Both glucose and fructose are simple sugars, or **monosaccharide's**, and have the same molecular formula of $C_6H_{12}O_6$. Select parts of plants that you expect to contain sucrose that you intend to use. You may also test some plant parts that you may not expect to find any sucrose.

Prepare your sample by taking a drop or two of liquid from the plant part that you wish to test the sucrose content of and place it on the lens underneath the plastic cover as pictured below. Close the plastic cap and look through the optical lens at the opposite end. A line should appear distinguishing a blue section from a lighter or white section. Depending on other compounds present the line may be clear or blurry. The line will indicate the percentage of sucrose in your sample that can be expressed as #g sucrose/ 100g solution. Record your results for each plant.

Product Knowledge: **Did you know that within a given species of plant nutritional content can vary?** A crop with a higher refractive index, ie higher Brix number, may not only have a higher sugar content, but may also be higher in certain nutrients. For example, in tomatoes, the amount of sugars present, as measured with a refractometer are at the highest level when the tomatoes are fully ripe, and correspond to the time when the phytonutrient lycopene is at its maximum level.

Refractometer

Drop is smeared on angled glass

References:

Anthon GE, LeStrange M, Barrett DM. Changes in pH acids, sugars and other quality parameters during extended vine holding or ripe processing tomatoes. *J Sci Food Agric* 2011 May;91(7):1175-81.

The Anatomy of Life and Energy in Agriculture. Anderson, Arden B. Acres U.S.A., Austin, TX, 2004.

Matter and Energy in the Biosphere: Fast 2 Foundational Approaches in Science Teaching 2nd ed. Pottenger III, Francis M., Young, Donald B., and Klemm, E. Barbara. Curriculum Research & Development Group, Honolulu, HI, 2001.

Plants and Society 6th ed. Levetin, Estelle and McMahon, Karen. McGraw-Hill, New York, NY, 2012.

Name ________________

Date ________________

Student Observation Log

Mass of water added to the round bottom flask ______________________

(remember 1g of water = 1ml because the density of water is 1 g/ml)

Initial temperature of the water (C°) ______________________

2nd T reading ______ 3rd T reading _______ 4th T reading _________

Final temperature of the water (C°) ______________________

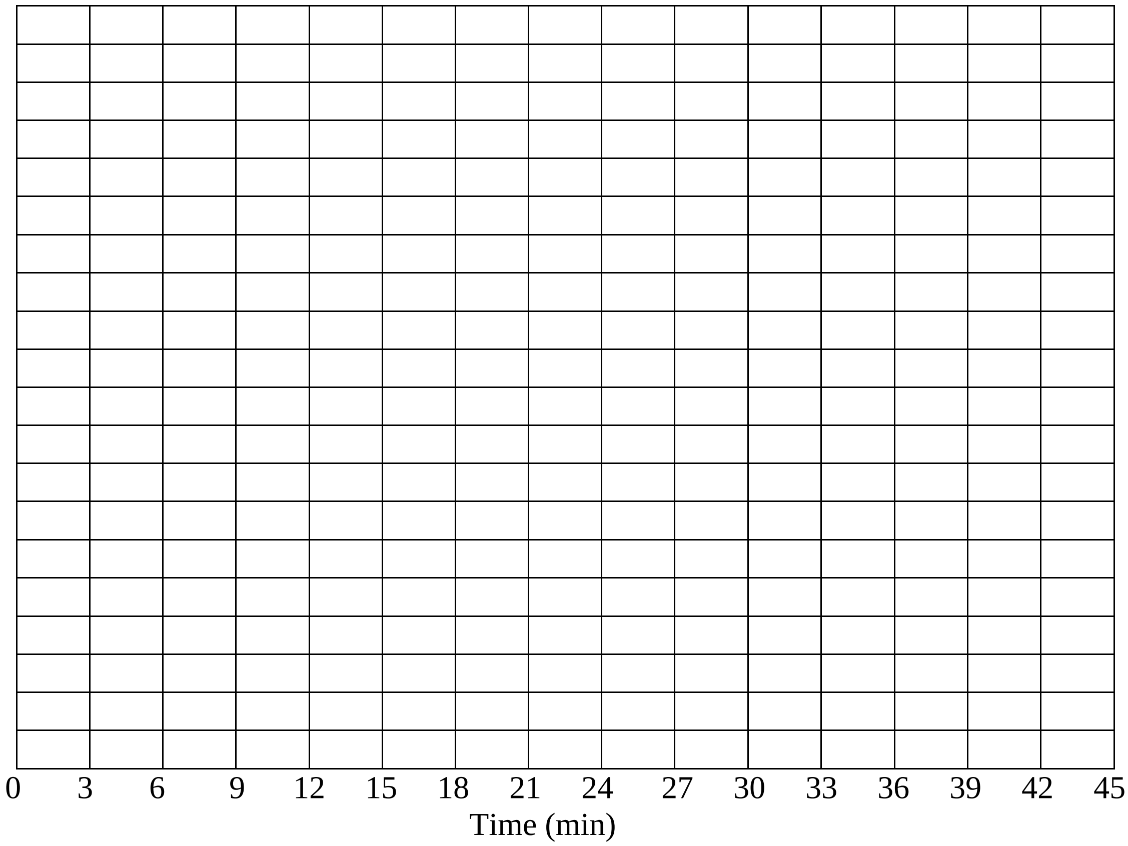
ΔTemperature of the water (Initial temp – final temp) (C°) ______________________

Calculate the Δ Energy water using the formula below. Show all work and units

ΔEnergy (calories) = ΔT(C°) * Mass H2O (g) * Specific Heat (1 calorie/ g C°)

Energy absorbed by the water ______________________

Graph the temp (x axis) vs time (y axis)



Record the Brix readings from your refractometer of at least two different plant parts

Plant	Plant part used	Brix Reading

Which plant showed the highest Brix reading? Which plant part?

Did you expect this? Why?